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PERFORMANCE ANALYSIS OF A PRE-FFT EQUALIZER DESIGN FOR DVB-T

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ABSTRACT

Conventional OFDM employs a guard interval to combat delay spread distortion of transmitted data. This reduces the efficiency of the OFDM transmission. The combined OFDM-Equalization strategy described here employs an Adaptive Equalizer to combat delay spread distortion and thereby facilitates the use of very short guard intervals and thus a more efficient OFDM modulation scheme. The OFDM receiver and the equalizer are described and performance is simulated for transmission in a multipath radio environment. It is shown that the combined OFDM-Equalization method offers improved bandwidth efficiency over the conventional method but performance is sensitive to additive noise.

INTRODUCTION

OFDM is the specified modulation method for the ETSI Terrestrial Digital Television Broadcast (DVB-T) standard. Conventionally, OFDM employs a cyclic extension of transmitted OFDM symbols to combat delay spread distortion.

In this paper, a novel equalizer design is proposed which allows for a considerable reduction in the length of the guard interval and thus offers a significant improvement in bandwidth efficiency.

Inter-Cell Interference in Single Frequency Networks (SFNs) manifests itself as very long delay spreads of the broadcast signal. This requires particularly long guard intervals for effective OFDM transmission. These long guard intervals can only be achieved by systems operating with an 8192 point FFT ('8k' mode). The pre-FFT Equalizer design described here obviates this limitation.

OFDM MODULATION

A conventional OFDM modulation process [1] is employed to produce cyclically extended OFDM symbols $x'(n,l)$ from an input data vector $X(k,l)$. k indexes the OFDM sub-band, n indexes the transmission symbol and l indexes the OFDM symbol. The ' indicates a cyclically extended sequence. $x'(n,l)$ is up-sampled, D-A converted and RF modulated to produce the transmittable signal $x_l'(t)$. The transmitted signal is distorted by delay spread and additive noise to produce a received signal $y_l'(t)$.

THE COMBINED OFDM-EQUALIZATION RECEIVER

The structure of an OFDM receiver employing a pre-FFT Equalizer is shown in Figure 1. Its function can be seen to be that of a conventional OFDM receiver [1] with the addition of the adaptive equalizing filter and a feedback path which generates $w'(n,l)$ - an estimate of the transmitted OFDM symbol based on the post decision output data, $W(k,l)$.

THE PRE-FFT EQUALIZER

The structure of the pre-FFT equalizer is shown in figure 2. This design is similar to that of a Decision Feedback Equalizer (DFE) that might be used in a single carrier system. An adaptation strategy combining the use of training sequences and decision directed adaptation is employed.
The equalizer output is defined as:

$$z'(n,l)=\sum_{j=-J_1}^{-J_1+n} c(j)y'((n-j-(N+M)),l+1)+\sum_{j=-J_1+n+1}^{0} c(j)y'((n-j),l)$$
$$+C_{out}(n)\sum_{j=1}^{n} c(j)z'((n-j),l)+\sum_{j=n+1}^{J_2} c(j)w'((n+(N+M)-j),l-1) \qquad (1)$$

where:

$$C_{out}(n)=0 \quad \text{for} \quad n=0$$
$$C_{out}(n)=1 \quad \text{for} \quad n\neq 0 \qquad (2)$$

Equalizer Training can be implemented in a conventional manner, such as by the LMS algorithm [3].

Decision Directed Adaptation is made more complex by the parallel transmission nature of OFDM. Since a complete OFDM symbol must be received before it can be processed by the FFT and the decision device, the equalizer can only be updated at intervals of the OFDM symbol period. Thus, at intervals of the OFDM symbol period the equalizer is adapted according to all the transmission sub-symbols for the preceding OFDM symbol. Also, it is necessary to input pre-decision symbols into the equalizer's feedback section until a complete OFDM symbol has been received and fed back to the equalizer. The LMS algorithm can be modified to adapt the equalizer in decision directed fashion and is now described by:

$$c(j,n,l+1)=c(j,n,l)+C_{ff}(j)\sum_{n=0}^{N+M+j-1}\Delta\varepsilon'(n,l)y'((n-j),l)+\sum_{n=N+M+j}^{N+M-1}\Delta\varepsilon'(n,l)y'((n-(N+M)-j),l+1)$$

$$\text{for}\quad -J_1\le j\le 0 \tag{3}$$

$$c(j,n,l+1)=c(j,n,l)+\sum_{n=0}^{j-1}\Delta\varepsilon'(n,l)w'((n+(N+M)-j),l-1)+C_{fb}(j)\sum_{n=j}^{N+M-1}\Delta\varepsilon'(n,l)w'((n-j),l)$$

$$\text{for}\quad 1\le j\le J_2 \tag{4}$$

$$\varepsilon'(n,l)=w'(n,l)-z'(n,l) \tag{5}$$

where:

$$C_{ff}(j)=0\quad\text{for}\quad -j=N+M$$
$$C_{ff}(j)=1\quad\text{for}\quad -j\ne N+M \tag{6}$$
$$C_{fb}(j)=0\quad\text{for}\quad j=N+M$$
$$C_{fb}(j)=1\quad\text{for}\quad j\ne N+M \tag{7}$$

As a result of feeding back pre-decision symbols into the equalizer, sensitivity to additive noise is increased.

SIMULATION RESULTS

To determine the sensitivity of the decision directed adaptation process to additive noise, performance has been simulated for uncoded transmission over the ETSI specified test channel 'F1'[2]. This channel is described by a Rician distribution (K=10, RMS delay spread 1.225 s). The MSE that the equalizer can maintain during decision directed adaptation (after a training sequence of 20 OFDM symbols) is plotted against SNR in Figure 3. Under noise free conditions, error falls to <10^{-5}.

CONCLUSIONS

The pre-FFT equalizer cancels delay spread of lengths up to the OFDM symbol length. Thus, combining the pre-FFT equalizer with '2k' OFDM and the minimum 1/32 guard interval achieves a system which can combat a longer delay spread than '8k' carrier OFDM with no increase in FFT complexity and much improved bandwidth efficiency. Thus, an improvement of up to 17% can be achieved over conventional OFDM in channels with severe delays, such as those in a Single Frequency Network.

The requirement to feed back pre-decision symbols in the equalizer requires that the SNR be sufficient to enable effective adaptation. For SNR above 20dB, the equalizer is sufficiently adapted such that output errors result predominantly due to the additive noise.

REFERENCES

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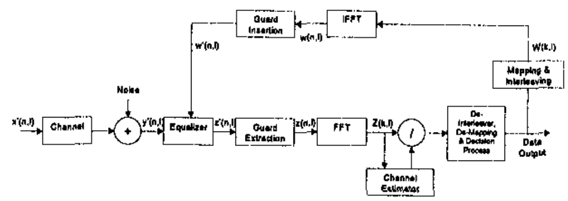

Figure 1. Combined OFDM-Equalization Receiver

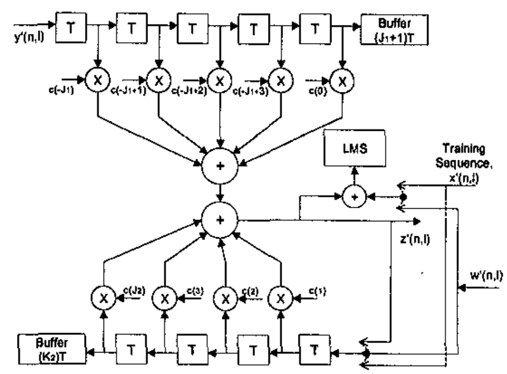

Figure 2. Pre-FFT Equalizer

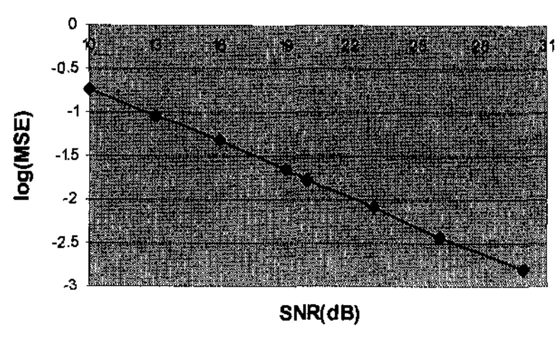

Figure 3 Equalizer Output Error vs. SNR